Vision Research 102 (2014) 93–96

Contents lists available at ScienceDirect

Vision Research

journal homepage: www.elsevier.com/locate/visres

Letter to the Editor

# Response to Maniatis critique of anchoring theory

The critique of anchoring theory by Maniatis reflects a close reading of the theory. My coauthors and I appreciate this and welcome the opportunity to achieve greater clarity.

## 1. Status of edge classification

Perhaps her most important charge is that edge classification, a key part of my earlier intrinsic image theory (Gilchrist, 1979), was abandoned by anchoring theory but more recently, surreptitiously re-introduced. In fact, edge classification was never abandoned. It morphed into the idea of framework segregation. The source of the confusion lies in the following sentence: "...the belongingness construction allows us to bypass the problem of edge classification, even though factors like edge sharpness and coplanarity, formerly thought to underlie edge classification, now show up as grouping factors." (Gilchrist et al., 1999, p. 805)

Some background is needed here. Anchoring theory emerged as an attempt to account for the overall pattern of errors in surface lightness perception, on the belief that the pattern of errors is the signature of the visual software. The literature reveals many kinds of lightness errors. But they fall into two broad classes: illumination-dependent errors (historically called failures of constancy) and background-dependent errors (historically called illusions). Thus the main challenge for a theory of errors is to find a formula that can account for these two seemingly different classes. For anchoring theory, the link lies in the concept of frame of reference, which had earlier been applied only to lightness constancy (Koffka, 1935) and failures of lightness constancy (Kardos, 1934). However lightness illusions also typically seem to involve frames of reference. Simultaneous lightness contrast, the prototype, is composed of two obvious side-by-side frameworks. Frameworks are also prominent in the Benary effect (1924) and White's illusion (1979), and various reverse contrast illusions, to name a few. As all these frameworks are supported by gestalt grouping principles, they can also be treated as perceptual groups, and the same can be said of illumination frameworks.

Of course the frameworks in these lightness illusions are not bounded by illumination edges. But in the language of perceptual grouping, segregation and grouping are intimately related; one is roughly the flip-side of the other. Thus the frameworks, or perceptual groups, central to anchoring theory depend on both segregation between frameworks (including edge classification) and consolidation within frameworks. Viewing frameworks as perceptual groups supported by both segregation and grouping factors allows the Kardos idea of co-determination to be applied to both broad classes of lightness errors, failures of illumination-independent constancy and failures of background-independent constancy. Edge classification retains an important role, but is supplemented (bypassed if you will) by grouping processes.

Many of the arguments made by Maniatis are predicated on her mistaken conclusion that edge classification had been rejected by anchoring theory.

## 2. Anchoring theory of simultaneous contrast

Maniatis challenges the anchoring account of simultaneous lightness contrast, specifically our claims that each of the two gray targets is perceptually grouped with its immediate background and the two backgrounds are segregated from each other. As for the first of these, it seems self-evident that each target is strongly grouped with its background, based on the important factor of surroundedness. However, the segregation of the two adjacent backgrounds is more problematic, especially given our claim, quoted by Maniatis, that, "two surfaces that are coplanar, adjacent and share a sharp boundary are maximally grouped for illumination" (Gilchrist et al., 1999, p. 783). Clearly the two backgrounds are coplanar and adjacent, and they share a sharp boundary. Here Maniatis may have spotted a previously unnoticed (or at least under-appreciated) contradiction in our writings.

Both sides of this apparent contradiction have ample support. On the one hand, our claim that adjacent, coplanar, sharp-bounded surfaces imply equal illumination (i.e., a single framework) is consistent with many reports. In such a pair of surfaces, the darker member is anchored by the lighter, such that the perceived reflectance (lightness) of the darker surface can be predicted by the luminance ratio of the darker surface to the lighter surface, multiplied by the perceived reflectance of the lighter surface. However, the lightness value of the darker surface rises as it is moved laterally away from the lighter, while remaining coplanar (Cole & Diamond, 1971; Dunn & Leibowitz, 1961; McCann & Savoy, 1991; Newson, 1958), as it is moved away from the lighter in depth, while remaining retinally adjacent (Coren, 1969; Gogel & Mershon, 1969; Kardos, 1934), or as it is rotated from the plane of the lighter surface, while remaining adjacent along one edge (Boyaci, Maloney, & Hersh, 2003; Ripamonti et al., 2004; Wishart, Frisby, & Buckely, 1997). According to this logic, the adjacent black and white backgrounds of a simultaneous contrast display are part of a single framework.

On the other hand, the two halves of the display seem to function as frameworks. If the two backgrounds are articulated with Mondrian-like patterns, the perceived difference between the targets increases, just as happens when fields of illumination are articulated (Burzlaff, 1931; Katz, 1935). The same thing happens when the two backgrounds are increased in size, suggesting they are subject to the law of field size, applied by Katz (1935) to fields of illumination.

http://dx.doi.org/10.1016/j.visres.2014.07.006

Perhaps a resolution of this apparent contradiction lies in the distinction between conditions at a local edge and the larger configuration. If we ignore the larger pattern we must conclude that the black and white backgrounds are part of a single framework. But in addition there are grouping factors that produce sub-groups. Each gray target is grouped with its background by sheer adjacency, as anchoring theory suggests and as Maniatis notes. Moreover, that adjacency is supplemented by surroundedness, producing a stronger grouping.

Pressing her challenge, Maniatis writes, "The fact is that some sharp boundaries produce the kind of segregation that leads to constancy effects, some to contrast effects, and some to neither." Again, you cannot look solely at what is happening at a local edge. When a sharp boundary occurs at a depth boundary (either a corner or an occlusion edge) or when it crosses a ratio-invariant X-junction, (strong) constancy effects result. When a sharp boundary occurs without these factors, but other grouping factors are present in the whole configuration, (weaker) contrast effects result.

It has often been noted that contrast and constancy effects go in the same direction. That is, a target in the brighter region (either brighter in illumination or higher in reflectance) appears darker than a target of equal luminance in the darker region. Earlier this led to attempts to account for lightness constancy using the same lateral inhibitory mechanism thought to explain simultaneous contrast (Cornsweet, 1970). Anchoring theory, conversely, suggests that backgrounds of different reflectance function as weak frameworks, even when they do not appear to differ in illumination level.

Is this justified? Kardos noted that we do not have the experience of a field of illumination just because an actual field of illumination is present. That would be an example of the experience error (Köhler, 1947). Perception of a field of illumination must be triggered by certain cues (factors, higher-order variables, call them what you will). Surely we all accept this rather obvious point. However it must be noted that these same cues can occur in the absence of an actual field of illumination. In these cases, according to anchoring theory, they produce a weak effect in the same direction.

Maniatis argues that the two targets in simultaneous contrast should be grouped together because they lie in the same plane. But in anchoring theory the targets are grouped together in one framework, called the global framework, while at the same time they are grouped separately into two local frameworks. Moreover, their grouping together is held to be about nine times stronger than their grouping in separate frameworks (Gilchrist, 2006, p. 317). Keep in mind that simultaneous contrast is a rather weak illusion. If the targets were anchored totally in their local frameworks, they would appear as different as black and white. If they were anchored totally in the global framework they would appear identical. Clearly the percept lies closer to the global prediction than to the local.

## 3. Recognition of earlier ideas

Suggesting that we have been "careless in asserting ownership of ideas" Maniatis cites two examples. The first is that our claim that the two main segmentation factors of fuzzy boundaries and depth boundaries is "indistinguishable from the view attributed by Gilchrist (2014) to Kardos (1934)". What exactly is her complaint here? Kardos has repeatedly been given credit for these ideas (Gilchrist, 2006; Gilchrist et al., 1999, pp. 66–74). Indeed before the anchoring theory paper (Gilchrist et al., 1999) Kardos had become virtually unknown. We have taken pains to insist that Kardos be given more credit (Gilchrist, 2006; Gilchrist & Annan, 2002). Second, she notes that the claim by anchoring theory that the black and white backgrounds in simultaneous contrast function as weak frameworks "parallels the view of Helmholtz". Have we been remiss in failing to note this parallel? Possibly.

Maniatis goes on to suggest that anchoring theory has added nothing to these ideas. However, in the case of Kardos, anchoring theory has extended his concept of co-determination to background-dependent failures of constancy (simultaneous contrast) whereas Kardos had applied it only to illumination-dependent failures. In the case of Helmholtz, anchoring theory has shown that the computationally difficult requirement of estimating the illumination level can be replaced with the far more tractable problem of grouping surfaces by common illumination. While no one has suggested how illumination can be estimated, we know that regions of common illumination are bounded by depth boundaries and blurred boundaries (penumbrae). But it should be noted that the problem of segmenting frameworks is not unique to anchoring theory. In order to estimate the illumination level in adjacent spatial fields of illumination, even Helmholtz would have to first identify those fields.

## 4. A test of anchoring theory vs. intrinsic-image theory

Maniatis refers to an experiment (Arroyo, Annan, & Gilchrist, 1995; reported in Gilchrist et al., 1999) we called a critical test because anchoring theory and my earlier intrinsic image theory made opposite predictions. Briefly, a spotlight is cast over half of a rather simple Mondrian pattern. The lightest patch within the spotlight is a middle gray square, which appears completely white and lighter than a real white outside the spotlight. This counterintuitive result is just what is predicted by anchoring theory, while intrinsic image theory predicts the opposite (white perceived lighter than middle gray). Maniatis raises a series of objections.

1. Maniatis asks how this result can be predicted by a theory that "apparently ignores obvious illumination boundaries". The answer, as noted above, is that the theory does not ignore illumination boundaries.
2. Maniatis states that we "viewed it as critical proof of the irrelevance of edge classification". Not true. We viewed it as a critical test between the two theories, as was clearly stated in our reports.
3. Maniatis then claims that the results and interpretation of Arroyo et al. (1995) are contradicted by those of Radonjic and Gilchrist (2013). It is not clear where there is a contradiction here, and Maniatis does not tell us. Likewise Maniatis claims that the results and interpretation of Arroyo et al. (1995) contradict those of Gilchrist, Delman, and Jacobsen (1983). Again, there is no obvious contradiction in the results. As for the interpretations offered in these 1983 and 1995 papers, they do indeed contradict one another because the earlier paper was written from the perspective of intrinsic image theory (Gilchrist, 1979), which was subsequently rejected in favor of anchoring theory. All of these experiments found substantial constancy with some degree of failure. Maniatis writes "That opposite results can both be rationalized as consistent with the anchoring theory reveals its lack of falsifiability/heuristic value." But again, these results are congruent with each other, not opposite. Maniatis has not revealed where a contradiction lies.
4. Maniatis argues that the Arroyo results show that "luminance values were compared and ranked across the penumbra" and this contradicts "a strong segregating role for penumbras." Is it possible that Maniatis has failed to grasp the core concept in anchoring theory – that of co-determination? A penumbra segregates a framework, yes. But it is not a watertight barrier. The crosstalk between frameworks, called global anchoring, must be factored in.

5. Maniatis writes “However, (presumably for reasons of methodological convenience), the bright side of the group of surfaces in these experiments contained no surface lighter than middle gray.” This was not done for methodological convenience but because it was this restriction of the bright side to shades of middle gray and darker that allowed our so-called critical test. Had a white or light gray been present on the bright side, the two theories we were testing between would have made the same prediction.

## 5. Figure/ground relations

Maniatis claims that “Anchoring theory has generally ignored or downplayed the issue of figure-ground relations.” This is unfairly pejorative. My coauthors and I have published a number of papers exploring a possible role for figure/ground relations in lightness (Bonato & Cataliotti, 2000; Gilchrist & Bonato, 1995; Li & Gilchrist, 1999). What we expected to be an effect of figure/ground turned out to be an effect of relative area, due to the larger area of ground versus figure. The absence of a figure/ground effect in those studies is an empirical finding, not a weakness in the theory. There is nothing in anchoring theory to prohibit a role for figure/ground and, indeed, we have presented an image (Economou, Zdravkovic, & Gilchrist, 2007; Gilchrist, 2006) that suggests such a role, one that is consistent with what Kardos (1934) called the principle of the next deeper depth plane (see Gilchrist, 2006, p. 72). For a surface that is isolated within its own depth plane, Kardos suggests that by default it groups with the next deeper depth plane rather than the next nearer. Further research on this is called for.

## 6. Fun with the word “limited”

Because Radonjic and Gilchrist (2013; see also Gilchrist & Radonjic, 2010) wrote that “the local lightness computation” is limited “to the target’s most immediate framework defined by a penumbra”, Maniatis claims that our statements “contradict the position of Gilchrist (2006), who continues to maintain that “frameworks” are not limited to regions of common illumination...” Here Maniatis is simply using the term “limited” in two different ways. Radonjic and Gilchrist are saying that a penumbra forms the limit of the local framework. Gilchrist (2006) is saying that factors other than penumbra can define a framework. In other words, a depth boundary can form the limit (or boundary) of a framework just as a penumbra can form the limit of a framework. Framework boundaries are not limited to penumbrae, even though in a given case, the penumbra serves as the limit of the framework.

## 7. Transparency

Maniatis suggests that the Arroyo results can be explained by assuming a “grayish overlay” on the bright side of the illumination edge. There are several problems with this proposal, the most obvious being that one simply does not perceive such an overlay. She cites Anderson and Winawer (2005) as saying that “the visual system has a bias to treat large reductions in contrast along an edge as indicating the presence of a transparent overlay.” However, no such conditions exist in this stimulus. There are several edges that cross the illumination boundary, but none show a reduction in contrast; the luminance ratio is preserved across the two fields of illumination, as Wallach noted long ago. The same error shows up in her discussion of the Allred et al. (2012) experiments, as Maniatis claims that “reduced contrast ratios” are consistent “with very bright or very low illumination.” Contrast ratios do not change with illumination level.

Regarding her analysis of the Allred et al. work, Maniatis writes, “a stimulus described by Allred et al. (2012) as consistent with the anchoring theory is actually not consistent with any of the anchoring theory’s claims to date, but is consistent with known principles of transparency.” Maniatis does not specify these known principles. The context suggests she is once again referring to the thesis of Singh and Anderson (2002) (cited by Anderson & Winawer, 2005) that perceived transparency is associated with “changes in Michelson contrast over aligned contours”, but no such changes over aligned contours are present in the Allred stimuli.

Maniatis complains that “The theory is also silent on the issue of perceived transparency...” This complaint is correct. As it stands, anchoring theory offers no account of perceived transparency. Nor has the theory formally incorporated an account of the perception of illumination level, ultimately an essential part of any theory of lightness. Currently those issues are best handled by layer models.

Perhaps the most important ongoing debate in lightness theory is that between layer models (Gilchrist, 1979; Singh & Anderson, 2002) and framework models (Bressan, 2006; Gilchrist et al., 1999). Layer models parse the image into overlapping layers, with an upper layer representing perceived illumination or transparency and a lower layer representing surface reflectance. Framework models typically parse the image into adjacent frameworks, much like different countries on a map of Europe. Both layer and framework models capture important insights while failing to account for important aspects of the problem. I believe that further development will lead to a model that combines the strength of both. The two approaches are probably not incompatible. But the fundamental difference in the units into which the image is parsed makes it difficult to see how they might be reconciled.

## 8. Loose ends

Maniatis writes, “It does not seem sensible to argue that the visual system is treating collections of non-contiguous surfaces – but not the areas between them -as lying under a common illumination.” But of course this can happen. A picket fence can be seen as uniformly illuminated even though the spaces between the pickets appear to have a different level of illumination.

Maniatis writes both that “the theory does not contain falsifiable principles” and “the theory continues to fail regularly”. Her contradiction here is obvious. If it is not falsifiable, how can it fail? Moreover anchoring theory has been presented along with a candid assessment of where it fails. See for example the section entitled Shortcomings of the Anchoring Model on pages 354–357 in Gilchrist (2006). How could such a section be written if the model were not falsifiable? And how many other models include such a section?

Maniatis claims that the limited clarity of anchoring theory gives it “a superficial (and scientifically inappropriate) advantage...” But if only those theories that are completely operationalized could be considered scientifically appropriate, there would probably be no scientifically appropriate theories in visual perception. Of course it is appropriate to construct and develop scientific theories, even if in their early stages, they contain some ambiguity.

Despite these differences in opinion, my colleagues and I welcome the kind of spirited debate exemplified by the Maniatis critique. We believe that such debate is an essential part of the scientific process and must necessarily lead to better theories.

## Acknowledgment

Supported by NSF Grant No.: BCS-1230793.

## References


Allred, S., Radonjic, A., Gilchrist, A., & Brainard, D. (2012). Lightness perception in high-dynamic range images: Local and remote luminance effects. *Journal of Vision, 12*.

Anderson, B., & Winawer, J. (2005). Image segmentation and lightness perception. *Nature, 434*, 79–83.

Arroyo, R., Annan, V., & Gilchrist, A. (1995). Which appears white, the highest luminance or the highest reflectance? *Investigative Opthalmology and Visual Science, 36*(4), S469.

Benary, W. (1924). Beobachtungen zu einem Experiment über Helligkeitskontrast (Observations concerning an experiment on brightness contrast). *Psychologische Forschung, 5*, 131–142.

Bonato, F., & Cataliotti, J. (2000). The effects of figure/ground, perceived area, and target saliency on the luminosity threshold. *Perception and Psychophysics, 62*(2), 341–349.

Boyaci, H., Maloney, L., & Hersh, S. (2003). The effect of perceived surface orientation on perceived surface albedo in binocularly viewed scenes. *Journal of Vision, 3*, 541–553.

Bressan, P. (2006). The place of white in a world of grays: A double-anchoring theory of lightness perception. *Psychological Review, 113*, 526–553.

Burzlaff, W. (1931). Methodologische Beiträge zum Problem der Farbenkonstanz (Methodological notes on the problem of color constancy). *Zeitschrift für Psychologie, 119*, 117–235.

Cole, R. E., & Diamond, A. L. (1971). Amount of surround and test inducing separation in simultaneous brightness contrast. *Perception and Psychophysics, 9*, 125–128.

Coren, S. (1969). Brightness contrast as a function of figure–ground relations. *Journal of Experimental Psychology, 80*(3), 517–524.

Cornsweet, T. N. (1970). *Visual perception*. New York: Academic Press.

Dunn, B., & Leibowitz, H. (1961). The effect of separation between test and inducing fields on brightness constancy. *Journal of Experimental Psychology, 61*(6), 505–507.

Economou, E., Zdravkovic, S., & Gilchrist, A. (2007). Anchoring versus spatial filtering accounts of simultaneous lightness contrast. *Journal of Vision, 7*(12), 1–15.

Gilchrist, A. (1979). The perception of surface blacks and whites. *Scientific American, 240*, 112–123.

Gilchrist, A. (2006). *Seeing Black and White*. New York: Oxford University Press.

Gilchrist, A. (2014). Perceptual organization in lightness. In J. Wagemans (Ed.), *Oxford Handbook of Perceptual Organization*. Oxford, U.K.: Oxford University Press.

Gilchrist, A., & Annan, V. (2002). Articulation effects in lightness: Historical background and theoretical implications. *Perception, 31*, 141–150.

Gilchrist, A., & Bonato, F. (1995). Anchoring of lightness values in center/surround displays. *Journal of Experimental Psychology: Human Perception and Performance, 21*(6), 1427–1440.

Gilchrist, A., Delman, S., & Jacobsen, A. (1983). The classification and integration of edges as critical to the perception of reflectance and illumination. *Perception and Psychophysics, 33*(5), 425–436.

Gilchrist, A., Kossyfidis, C., Bonato, F., Agostini, T., Cataliotti, J., Li, X., et al (1999). An anchoring theory of lightness perception. *Psychological Review, 106*(4), 795–834.

Gilchrist, A., & Radonjic, A. (2010). Frameworks of illumination revealed by probe disk technique. *Journal of Vision, 10*(5), 1–12.

Gogel, W. C., & Mershon, D. H. (1969). Depth adjacency in simultaneous contrast. *Perception and Psychophysics, 5*(1), 13–17.

Kardos, L. (1934). Ding und Schatten [object and shadow]. *Zeitschrift fur Psychologie, Erg. bd 23*.

Katz, D. (1935). *The world of colour*. London: Kegan Paul, Trench, Trubner & Co.

Koffka, K. (1935). *Principles of Gestalt psychology*. New York: Harcourt, Brace, and World.

Köhler, W. (1947). *Gestalt psychology*. New York: Liveright.

Li, X., & Gilchrist, A. (1999). Relative area and relative luminance combine to anchor surface lightness values. *Perception and Psychophysics, 61*(5), 771–785.

McCann, J. J., & Savoy, R. L. (1991). Measurements of lightness: Dependence on the position of a white in the field of view. *Proceedings of the SPIE, 1453*, 402–411.

Newson, L. J. (1958). Some principles governing changes in the apparent lightness of test surfaces isolated from their normal backgrounds. *Quarterly Journal of Experimental Psychology, 10*, 82–95.

Radonjic, A., & Gilchrist, A. (2013). Depth effect on lightness revisited: The role of articulation, proximity and fields of illumination. *iPerception, 4*(6), 437–455.

Ripamonti, C., Bloj, M., Hauck, R., Mitha, K., Greenwald, S., Maloney, S., et al (2004). Measurements of the effect of surface slant on perceived lightness. *Journal of Vision, 4*, 747–763.

Singh, M., & Anderson, B. L. (2002). Toward a perceptual theory of transparency. *Psychological Review, 109*, 492–519.

White, M. (1979). A new effect of pattern on perceived lightness. *Perception, 8*(4), 413–416.

Wishart, K., Frisby, J., & Buckely, D. (1997). The role of 3-D surface slope in a lightness/brightness effect. *Vision Research, 37*, 467–473.



Alan Gilchrist

*Rutgers University, 101 Warren St., Newark, NJ 07102, United States*

*E-mail address:* alan@psychology.rutgers.edu


Available online 27 July 2014